Exhibit G

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Optical Near Field Measurements and Ray-Tracing Simulations of Coated and Uncoated Halogen Lamps for Glare Analysis

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ABSTRACT

Automotive lamps for headlights are constantly reevaluated for causes of glare issues. Lead wires, glass, sockets and even filaments reflect and/or scatter the light from the filament into undesired directions, possibly causing glare. The best way to account for scattered light in the design process is to measure the near field radiation pattern. A high-resolution camera on a goniometer is used to characterize the headlamp. The results are further analyzed in an optical ray-tracing package. This paper will look at the new double filament lamp (H13) in respect to glare as well as the effect of "cool blue" absorption coatings. Measurements of the emission patterns of the lamps with and without coating are compared. A ray-tracing model will simulate the effect of the coating and amplify the effect to determine how much increase in scattering is necessary to cause a glare problem. The goal is to show that the measured effect of absorption coatings on lamps is too small to cause glare.

INTRODUCTION

With the introduction of high color temperature discharge lamps, the desire to copy the blue appearance and to find an intermediate solution for already existing halogen headlamps systems, produced a series of coated halogen lamp products. They can be divided in lamps with absorptive and with interference coatings. The interference coatings reflect the longer wavelength light back into the lamp, which causes ghost images. This light might exit the lamp in an uncontrolled way, causing glare or color deviations. Absorptive coatings absorb the longer wavelength light without creating more ghost images. However, a general concern still remains, whether or not the coated lamps are able to replace the existing uncoated lamps in any already existing reflector system. Past investigations have compared lamps successfully in one or few reflector systems, but the question remains, whether there is a chance for the coating to cause glare. This study will compare a regular

H13 and a coated H13 lamp (H13-CB) on a lamp level, by measuring the near field emission distribution. Since the H13-CB lamp is not in production yet and the CB-coil has not been designed yet, both lamps, coated and uncoated, will have the same coils. The total luminous flux of the CB lamps has been scaled up to the same total flux as the uncoated lamp, in order to allow for easier comparison.

SOURCE CHARACTERIZATION

The typical lamp characteristics, such as total luminous flux, color or far field emission patterns are integrated values and assume that the lamp is a point source. The origins of the emitted light, may it be coil, glass or lead wires are ignored. For most classifications and simple designs this information is enough, but if more accurate calculations are desired, a near field emission distribution is required. The near field measurements are a series of pictures of the light source from each angle on a sphere around the light source. This allows not just to determine how much light is emitted in each direction, but also where it comes from. The resulting data can be stored as pictures or after processing as a ray-file, which is used in optical simulation software packages. These files can be rather large and can easily reach hundreds of Megabytes. The near field measurement system consists of a goniometer and a CCD – camera, which is rotated in the goniometer around the light source (fig.1). The camera can look at the light source from every angle except region near the mount of the lamp. This blind spot is typically not a problem, since the lamp does not emit light in this direction, because its own base or connector shadows the light. The goniometer's resolution is 0.01°, but for a full sphere scan the data amount would be unmanageable. A reasonable step size without sacrificing detail is about 1° to 2°. The CCD camera has picture size of 1300x1000 Pixels with a 12 Bit resolution. This is more than adequate to resolve the features of the lamp as well as meet the dynamic range requirements for the difference between the bright coil and the faint reflexes from the glass. 12 Bit allows a

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measurement of over 3.5 orders of magnitude. Even higher Resolution up to 24Bit can be achieved by successive Imaging with different exposure times. The z-axis passes through the center of the low beam coil. The origin is placed at the bottom end of the low beam coil. For headlamps this position is adjusted more accurately than the center of the coil. (fig. 2).
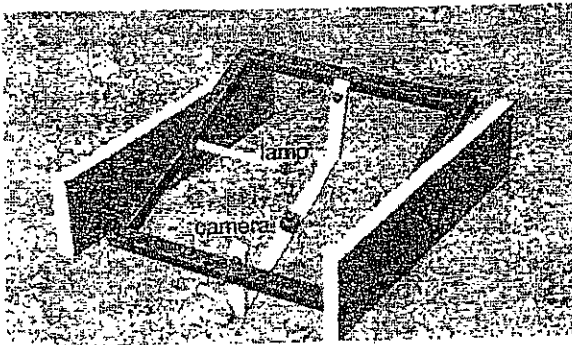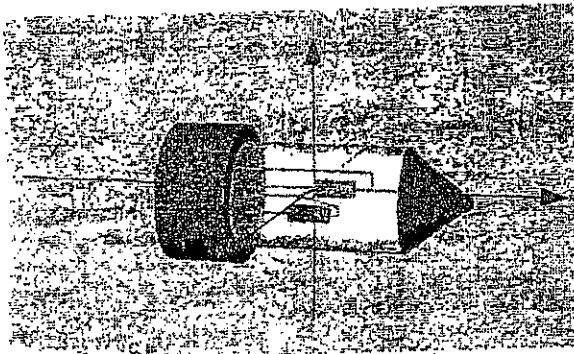

Figure 1: Goniometer with CCD camera

Figure 2: Lamp orientation in coordinate system

Two lamps, a regular uncoated H13 lamp and a coated H13 lamp (H13-CB) are measured. A full sphere scan with 1° resolution is taken. The pictures are processed into a ray-file of 500 Mio rays. For further processing smaller files with randomly extraction of 5 and 10 Mio rays are used.

FAR FIELD COMPARISON

The far field is calculated by integrating the near field measurements across the lamp surface. The results for the H13 and H13-CB lamp are shown in figure 3 and 4. The structure in the far field emission patterns can easily be related to the parts of the lamp. The H13 does not have a glare shield, but uses the position of the high beam coil to block the light from the low beam coil going towards the lower part of the reflector. This shadow is visible in figure 3 at 225° and figure 4 at 270°. This region would be most susceptible to cause glare in the beam pattern. Both emission patterns are almost

identical; therefore the coating does not introduce a significant change in the far field pattern.
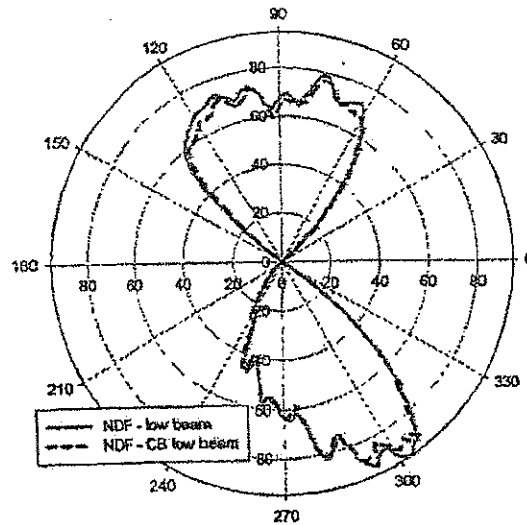

Figure 3: Far Field Emission of H13 and H13-CB along the polar angle
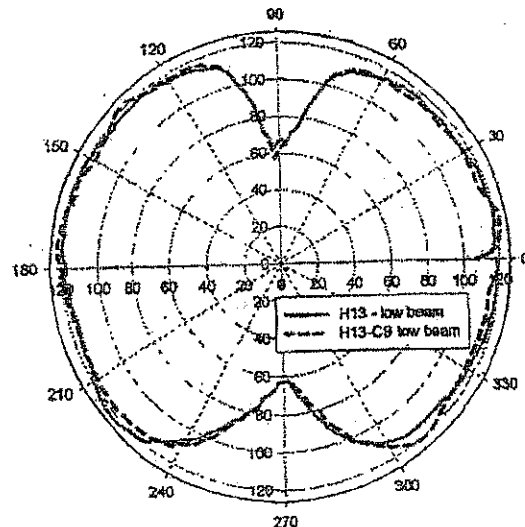

Figure 4: Far Field Emission of H13 and H13-CB along the azimuth angle
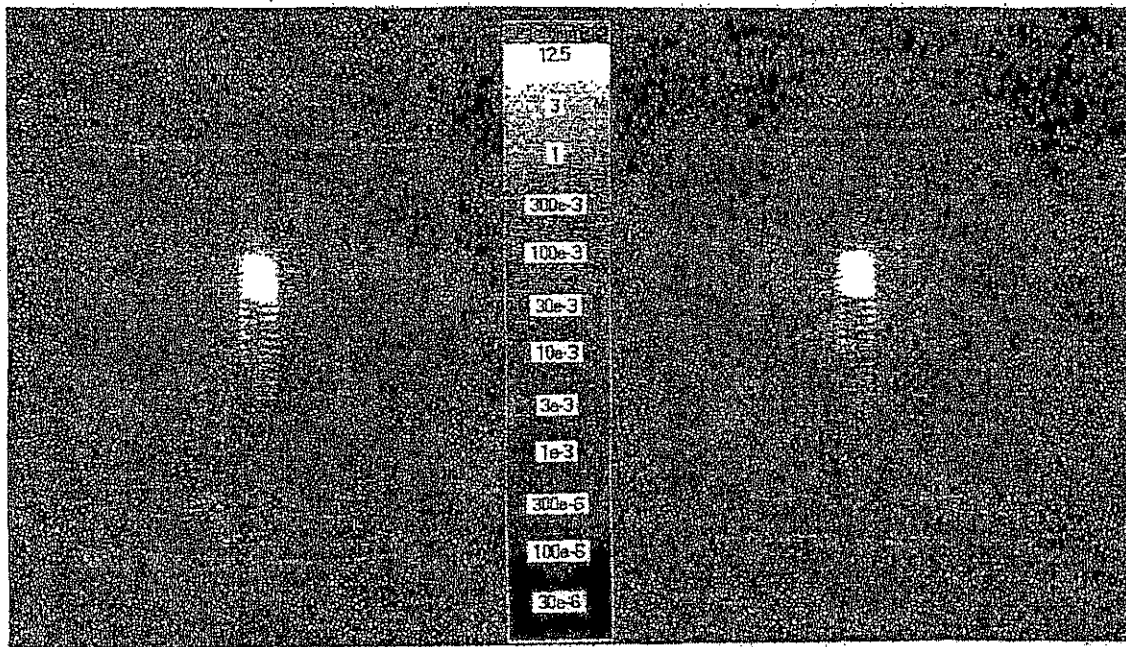
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Figure 5: H13 (left) and H13-CB (right), low beam coil lit,
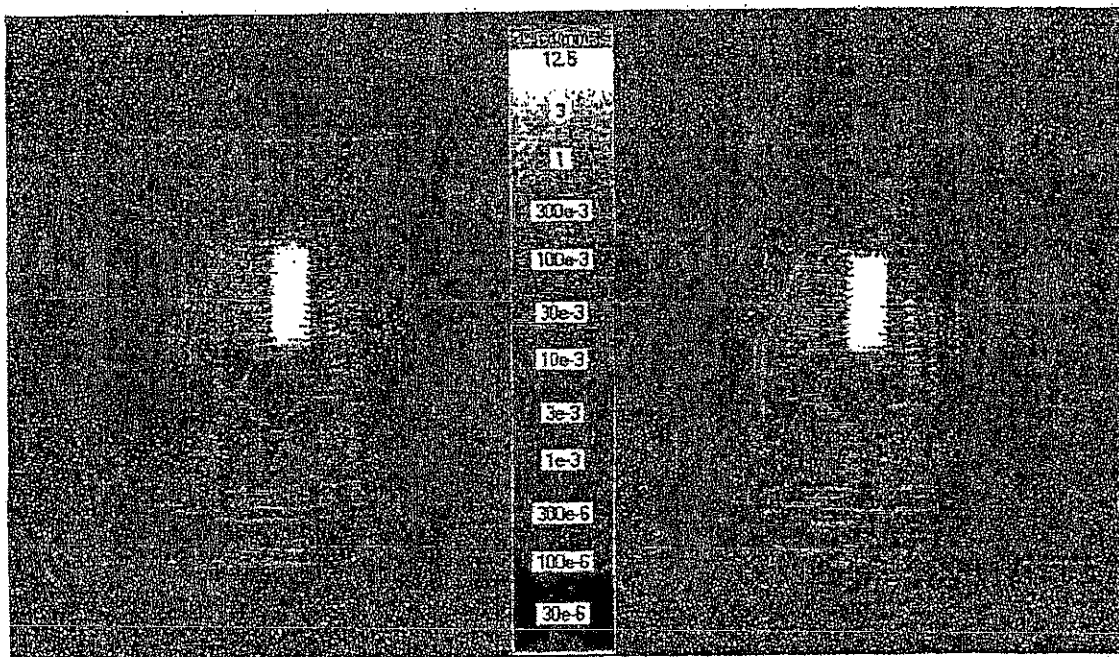view from bottom

Figure 6: H13 (left) and H13-CB (right), low beam coil lit,
view from side

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NEAR FIELD ANALYSIS

Instead of analyzing the emission direction, the rays can be retraced back into the lamp and divided into rays from the coil and rays from other position, which are generally undesired; lets call them scattered rays. Further classification of the scattered rays, whether they come from the glass or from a lead wire cannot clearly be done. Therefore the analysis is limited to identify the deviation from an ideal halogen source, which would only emit rays coming from the coil. For this analysis the optical simulation software ASAP is used. A cylinder is placed into the coil position and the rays are traced backwards. All rays, which hit the coil or miss the coil are integrated. The results are normalized to the total output flux of the lamp and summarized in table 1.

coil	scattered flux in % of total flux	effect of coating in % of total flux
H13 – low beam	14.0	0.1 %
H13-CB – low beam	14.1	
H13 – high beam	14.3	0.1 %
H13-CB – high beam	14.4	

Table 1: Scattered flux for H13 and H13-CB

The ratio of scattered flux versus total lumens is a measure how ideal the source is. The higher the ratio the more glare problem might be expected. This number includes all scattered light, including ghost images, reflections from the other coil and the lead wires etc. The difference of the scattered fluxes for both lamps will show the effect of the coating, which is here 0.1% of the total flux. This is almost not detectable with this method and the effect of the coating can be assumed as negligible. However in order to get a more accurate estimate of the effect of the coating the dynamic range needs to be increased.

HIGH DYNAMIC RANGE LUMINANCE ANALYSIS

Overlaying a series of pictures from the same camera position, but different exposure times increases the dynamic range, in this case up to 24 Bits. This covers a range of 7 orders of magnitude. The coil's luminance is close to 12×10^6 cd/m2 . The lowest luminance, which can be resolved, would be about 2 cd/m². This resolution is definitely enough to identify any change in glass wall scattering.

Slight differences in the glass wall scattering are visible, more so in the bottom view (fig. 5) than in the view from the side (fig. 6). In both views, the scattered light from the glass walls has a luminosity, which is 3 orders of magnitude smaller than the one of the coil. A qualitative comparison of the pictures already shows, that the appearance of the lamp features and the sharpness of the wire edges are the same with or without coating. This indicates that the scattering effect of the coating, if at all exists is very small. In order to attempt a quantitative analysis, the pictures are compared by integrating the luminosity [cd/mm²] only over the areas of

scattered light from the glass walls. The result of the integration is an intensity [cd], which is the amount of light coming from the entire integrated area from the lamp towards the observer within a solid angle defined by the camera (table 2).

Picture – lamp	wall scatter [cd]	difference between lamps [cd]	Coil intensity [cd]	Difference scatter vs. coil
4 – H13	1.09	0.25 cd	26.3 cd	0.9%
4 – H13-CB	1.34			
5 – H13	2.13	0.02 cd	45.7 cd	0.04%
5 – H13-CB	2.15			

Table 2: Integrated luminosity for NDF and NDF-CB

The difference between the two lamps is the most in the bottom view (fig. 4a,b), but it is, in respect to the coil intensity, very small. In the side views (fig. 5a,b) the difference is negligible. The fact that the effect of the coating differs depending on the viewing angle indicates a localized cause, for example inhomogenities in coating or glass surface and the fact that the effects are so small, raises the question, how much is caused by the coating and how much is due to sample to sample variations in coil position, glass surface etc.

SIMULATED SCATTERING SOURCE IN A REFLECTOR SYSTEM

The measured differences between the coated and uncoated lamps are very small. The difference in luminous flux between the coated and the uncoated lamp is 0.1% of the total luminous flux. In an optical ray tracing simulation the effect of scattered light from the coating on the far field was calculated. A H13 lamp was modeled inside a typical H13 reflector. The scattered light was simulated as lambertian radiation, uniformly distributed over the glass cylinder of the lamp. The simulation results quantify the contribution in the beam pattern of a typical H13 reflector system (figure 7).

SAE test points	Max. intensity [cd]	Scattered light (fig.7) [cd]
10 U – 90 U	125	≤ 0.5
1 U – 1.5L to L	700	≤ 3.5
0.5 U – 1.5L to L	1000	≤ 3.5

Table 3: Comparison of the scattered light from the coating (from fig.6) with the SAE test points for the headlamp beam pattern

In table 3 the simulation results from Figure 7 are compared with the most critical SAE test points for glare. The additional intensity caused by the coating is significantly less than the SAE specification. Uncertainties of the measurements and production variations of the reflector system and the lamp will be higher than the contributions of the coating.
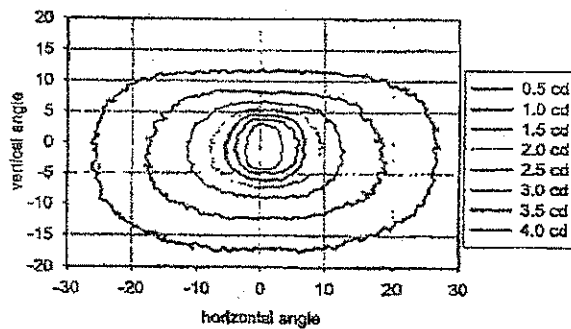
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Figure 7: Simulation results: Effect of the scattered light from the coating on the beam pattern of a H13 reflector

CONCLUSION

An H13 lamp was coated with a "cool blue" coating and compared with an uncoated lamp. The scatter light analysis have shown that the differences are negligible and that the coating does not introduce sufficient enough scattering to cause glare in a reflector system, which was designed for an uncoated H13 lamp. The detected differences are so small and localized, that it is debatable, whether or not the effects are entirely caused by the coating. In order to determine how much of the effects are caused by sample to sample variations, such as coil position, lead wires and glass surface conditions, further analysis of a number of production samples are planned.

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